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(Revision of ANSI C63.12-1984)

American National Standard

for electromagnetic compatibility limits—recommended practice

american national standards institute, inc.

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(Revision of ANSI C63.12-1984)

American National Standard

for Electromagnetic Compatibility Limits—Recommended Practice

Accredited Standards Committee On Electromagnetic Compatibility, C63

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Foreword

(This Foreword is not part of ANSI C63.12-1987.)

The problem of electromagnetic compatibility has existed from the early days of radio when spark gaps were used for transmitting and receivers picked up many signals unintentionally. Radio transmission has evolved from those early days into a highly sophisticated science. However, the need for compatibility is even greater today than it was in earlier times since modern society has come to depend on radio waves in all facets of life from garage door openers and licensed broadcasting to sophisticated airplane and missile guidance systems. The proliferation of unintentional radiators such as personal computers and video games has increased the need for electromagnetic compatibility.

The need for an electromagnetic compatibility document was recognized by the American National Standards Committee C63, and a draft standard of this document was approved by C63 on August 5, 1977. The first official issue of the standard was approved December 2, 1983, and published by the IEEE in 1984. Changes in national and international standards since that time prompted Committee C63 to request that Subcommittee No 1 undertake revision of C63.12. The present document is the result of that undertaking.

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At the time that the Accredited Standards Committee on Electromagnetic Compatibility, C63 approved this standard it had the following membership:

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Contents

American National Standard

for Electromagnetic Compatibility Limits—Recommended Practice

1. Scope

Over the years many electromagnetic compatibility measurement and control standards have been developed. Many of these are of concern to particular classes of devices such as receivers, transmitters, incidental radiation devices, etc. In establishing limits, it is necessary to relate the measurement technique used to determine compliance with a given limit to the field conditions under which the device being controlled will actually operate. The purpose of this standard is to set forth, at least for reference purposes, a suggested set of limits which may find general application. This document does not set specific limits. It presents a rationale for developing limits and recommends a set of limits that are representative of current practice. In practice these limits[1] may be adjusted in particular applications as circumstances dictate. This document does not consider limits for industrial, scientific, and medical (ISM) equipment which specifically uses radio frequencies as a major part of its operation.

As part of the development of limits, the following parameters should be considered:

(1) The general properties of both man-made and natural environmental noise

(2) An understanding of the devices commonly used for measurement of radio noise and their properties, which will assist the practitioner in selecting such equipment and associated measurement techniques for the particular application

(3) The rationale that can be used in selecting a consistent set of limits for emission and immunity, (susceptibility) subject to various environmental constraints (good engineering practice)

These practices are intended to be applicable to individual equipment as well as systems of various sizes and, if properly applied, will provide guidance for obtaining both intrasystem and intersystem compatibility.

This standard is organized as follows: Section 2 references instrumentation and measurements methods, Section 3 contains a list of definitions, Section 4 describes environmental radio noise, and Section 5 describes the selection of measurement parameters. Section 6 discusses limit setting, and Section 7 is a list of references.

Appendixes A, B, and C discuss the measurement of amplitude distribution, the measurement set envelope amplitude distribution, and the amplitude probability distribution, respectively.

2. Instrumentation and Measurement Methods References

Instrumentation and measurement methods used for determining electromagnetic compatibility (EMC) are described in more detail in ANSI C63.2-1987 [1][2] and ANSI C63.4-1981 [2], and in forthcoming immunity documents to be added to them. These documents should be reviewed before proceeding to make measurements. A forthcoming ANSI document (see 7.2, footnote 9), Guide to Electromagnetic Compatibility Standards and Procedures (PC63.8), contains information on various EMC standards in current use in the United States. When American National Standards referred to in this standard are superseded by a revision approved by the American National Standards Institute, the revision shall apply.

[1] It should be noted that the limits and measurement techniques described herein are proposed for general use to the extent that they are not covered in regulations of Federal Government agencies. Clearly, in circumstances where such regulations apply and could be considered to be in conflict with these practices, the government regulations take precedence.

[2] Numbers in brackets correspond to those of the references listed in Section 7.

3. Definitions

amplitude probability distribution (APD). The fraction of the total time interval for which the envelope of a function is above a given level x.

atmospheric radio noise. Noise having its source in a natural atmospheric phenomenon.

average crossing rate. The average rate at which a specified level (zero if not specified) is crossed in the positive-going direction.

distribution function [$P(x)$]. The probability that a parameter is less than a given value x.

electromagnetic compatibility (EMC). The ability of a device, equipment, or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

envelope amplitude distribution (EAD). A cumulative distribution of the impulse response positive crossing rates of a bandpass filter at different spectrum amplitudes.

environmental radio noise. The total electromagnetic disturbance complex in which an equipment subsystem or system may be immersed, exclusive of its own electromagnetic contribution.

immunity (to a disturbance). The ability of a device, equipment, or system to perform without degradation in the presence of an electromagnetic disturbance.

impulsive noise. Electromagnetic noise that, when incident on a particular device or equipment, manifests itself as a succession of distinct pulses or transients.

NOTES: (1) The frequency spectrum of these disturbances must be substantially uniform over the useful pass band of the transmission system.
(2) The same source may produce an output characteristic of impulsive noise in one system and of random noise in a different system.

intersystem electromagnetic compatibility. The condition that enables a system to function without perceptible degradation due to electromagnetic sources in another system.

intrasystem electromagnetic compatibility. The condition that enables the various portions of a system to function without perceptible degradation due to electromagnetic sources in other portions of the same system.

noise amplitude distribution (NAD). A distribution showing the pulse amplitude that is equalled or exceeded as a function of pulse repetition rate.

power density. Emitted power per unit cross-sectional area normal to the direction of propagation.

probability density function [p(x)]. The derivative of the distribution function $P(x)$.

pulse count. The number of pulses in some specified time interval.

random noise. Electromagnetic noise the values of which at given instants are not predictable.

NOTE: The part of the noise that is unpredictable except in a statistical sense. The term is most frequently applied to the limiting case in which the number of transient disturbances per unit time is large so that the spectral characteristics are the same as those of thermal noise. Thermal noise and shot noise are special cases of random noise.

4. Description of Environmental Radio Noise

The minimum level required for satisfactory reception of desired radio or control signals is determined by the level of environmental radio noise or undesired signals with which the desired signal must compete. Several types of radio noise may influence reception; however, with a particular system and environment one type will generally predominate at a given time, especially if a receiver is located physically near a specific source.

All sources of radio noise can be divided into two general groups, wide bandwidth and narrow bandwidth noise, in which the distinction is usually based on comparison with the bandwidth of a typical receiver. Wide bandwidth noise is frequently impulsive and can be divided further into two groups, natural and man made. Narrow bandwidth noise is usually generated by a variety of restricted radiation devices—industrial, scientific, medical (ISM) equipment, licensed radio transmitters, and incidental radiating devices operating with fast rise time oscillations or microprocessors or both. These devices generally radiate radio frequency energy over a limited portion of the spectrum clustered around discrete frequencies. Licensed radio transmitters also radiate a broad noise spectrum near their carrier frequency.

To the extent that radio noise varies, a time-domain statistical description is necessary to characterize it. Just how much detail is needed in the description depends upon the desired accuracy of predicting degradation and the information bandwidth of the system with which it may interfere. In general, the noise variations take place in spectrum amplitude, which may be associated with a change in impulse rate and may occur in periods of time ranging from fractions of a second to periods of a year or more as in the case of atmospherics.

In determining how to conduct measurements of radio noise sources, the following criteria should be kept in mind [3]:

(1) Since many measurements are usually required in many areas, parameters should be simple and economical to measure and analyze

(2) Parameters should be such that the interference effect of the noise on the various types of receiving systems likely to be affected can be accurately judged

(3) Parameters should be such that they can be related to such predictors as, for example, population and vehicle density.

(4) Parameters should be useful in identifying the source of the measured noise

The amplitude probability distribution (APD) and the noise amplitude distribution (NAD) are time-domain statistical distributions that have been measured frequently. They give detailed information about the noise, and they can be used to evaluate the effects of a given type of noise on a given communication system with varying degrees of accuracy. They are briefly described in Section 5. Other distributions have been measured.

For stationary distributions, relatively simple real-time logic functions can be utilized in a measurement system to obtain the required data, generally presented graphically. Another approach is to measure certain statistics of the distribution, such as the average, peak, rms, quasi-peak, and average logarithm, rather than the distribution itself [8], [21]. One or more of them can be used to predict the effects of a measured radio noise on the performance of a specific communication, navigation, or other electronic system *provided* the repetition rate, bandwidth product, or other vital information is known.

5. Selection of Measurement Parameters

It is apparent that no single parameter can be selected as the best for measuring interference effect on a wide variety of services, for example, voice, telegraph, facsimile, data, and television (TV). There is also a wide range of needed service quality. In the case of interference from atmospheric radio noise, a parameter which is related to very occasional lightning flashes should be chosen if a very high quality of service is desired 100% of the time. Otherwise, a measure related more nearly to the average or rms level might be more meaningful.

There has been an effort, particularly in teletype and data transmission, to use various coding techniques to improve the performance of radio circuits in the presence of fading and interference with varying degrees of success. It has become apparent that in the real world, interference (or severe fading) tends to occur over limited periods of time and frequently is capable of destroying during its presence any signal, however coded. This has led to the consideration of redundancy spaced in time rather than in frequency or space in order that occasional bursts of radio noise will not cause uncorrected or unnoticed errors in coded transmissions. The type of coding undoubtedly affects the weighting, which should be given in deciding on noise measurement parameters.

The interference produced by a continuous wave (CW) signal may vary critically with the phase and amplitude relation between it and the desired signal. For example, for AM broadcasting, regulations require stations to maintain a ±20 Hz carrier tolerance in order to keep inaudible the beat note between stations on the same frequency. In this case, the interference originally caused by the carrier beats has been so reduced that the modulation from the interfering stations now predominates. Similarly, to reduce interference, 10 or 20 kHz frequency offsets of television stations are employed. Impulsive interference having certain repetition rates may prove especially destructive to TV reception. The design of the TV receiver synchronization circuit is critical in this regard.

If a communication system performance is degraded by a particular form of radio noise, the system might be redesigned to reduce the impact of that radio noise. An example is the use of limiters in FM and AM voice systems to reduce local impulsive radio noise effects. Thus, development of measuring methods should be closely allied to interference studies since the utility of the measurements will hinge largely on their correlation with caused interference.

5.1 Single Parameter Measures

5.1.1 Quasi-Peak. Historically, radio noise measurements were first made to protect AM broadcasting. Reference [6] shows that the quasi-peak meter provides, on the basis of listening tests, good correlation of interference to AM receivers created by three different types of individual noise sources. There have been several sets of charge and discharge time constants used, in particular 1–600, 1–160, and 10–600 ms, depending upon the application and frequency range [1].

5.1.2 Peak. In the United States peak measurements (either metered or slideback) have been widely used in military standards and for measurements of impulsive (ignition) interference. As a means of evaluating the radiation from a variety of incidental radiation devices, the peak reading meter is limited. For example, the radiated radio noise from 1-100 ignition systems could produce the same peak reading whereas the associated power would vary by 20 dB

5.1.3 RMS. The rms value has been used in the measurement of atmospherics and other forms of random noise. It has the advantage that it can be related to the spectral power density which, for noise with a flat spectrum, is independent of bandwidth. For some types of transmissions it can be correlated quite well with interference effect.

5.1.4 Average. The average is used most commonly for measuring the level of modulated radio carriers. It is also used in characterizing atmospherics by means of the parameter V_d defined as the ratio of the rms to the average value.

5.2 Statistical Measures

Reference [24] and others have given definitions and descriptions of the hierarchy of probability distributions required for the description of a random process. In practice it is almost never feasible to obtain this complete description for man-made radio noise. It has been found that, for additive interference (Gaussian, atmospheric, man made, and the like), performance can be determined for most systems from the amplitude probability distributions of the noise and of the signal envelopes. However, since some forms of additive interference are correlated in time, higher order distributions are, in principle, also required for some systems. References [5], [9], [16], [26], [27], and [32] give specific examples of such studies for digital systems, while references [24], [25], [30], [31], and [33] and their bibliographies treat systems in general and give specific examples for both analog and digital systems. For the optimum design of some communication systems, all of the above statistics may be required.

Since any measurement of noise is made on the detected radio noise with a receiving system having a finite bandwidth and not on the radio frequency voltages in the receiving antenna, the receiving system characteristics must be considered. That is, differences between the receiver experiencing interference and the receiver used in the measurement program must be taken into account. Indeed interference appearing to originate in isolated impulses on one (wideband) receiver could appear as originating in overlapping noise bursts in another (narrow-band) receiver.

5.2.1 Envelope Amplitude Distribution (EAD). EAD is defined in Section 3. The use of EAD as a method of impulsive noise measurement is limited since each type of filter and each bandwidth has a different impulse response. Its main usefulness is to show the limitations of measurement equipment caused by Gaussian noise generated in the receiver itself.

5.2.2 Amplitude Probability Distribution (APD). APD is defined in Section 3. The amplitude of the received signal levels are expressed in either decibels, rms, or dB above kTB. The APD is usually presented on Weibull probability paper.

In the case of atmospheric radio noise, which generally has a constant noise slope of 10 dB per octave, it has been found that an approximation of the APD can be determined by 3 simple parameters: the antenna radio noise factor F_a, the deviation V_d of the average envelope of voltage from the rms envelope voltage, and the deviation L_d of the average log of envelope from its rms value. Both V_d and L_d are expressed in decibels [4], [10], [11]. It has also been found that L_d is well correlated with V_d, though this might not be the case with some other form of impulsive noise [29]. The noise predictions based on the rms envelope value and V_d given in [7] can be converted to impulse rates. Reference [23] gives APD data for man-made noise.

5.2.3 Noise Amplitude Distribution (NAD). NAD is defined in Section 3. The NAD is usually presented on a graph with the spectrum amplitude [dB (μV/MHz)] on the linear ordinate and the impulse rate on the logarithmic abscissa. For impulsive noise, the noise data presented by the NAD is independent of both bandwidth and the characteristics of measurement equipment used to make a noise measurement, provided the highest impulse rate is no greater than about 30% of the receiver bandwidth and the impulses are largely nonoverlapping after passing through the measuring receiver.

Single parameter measurements can easily be determined from the NAD for comparison purposes. Peak values can be found by inspection since they correspond to the lowest impulse rate. Quasi-peak and rms values can be found by graphical methods.

The interference effect of impulsive noise can be evaluated by the following method:

(1) Measure impulse noise tolerance (isodegradation curve) of the receiving equipment in accordance with applicable standards

(2) Measure NAD

(3) Perform NAD overlay on impulse noise tolerance graph and determine degradation

6. Limit Setting

This section develops the rationale for, and suggests guidelines for, electromagnetic emissions from unintentional radiators. It does the same for corresponding immunity characteristics. A basis for establishing general interference/emission objectives is first developed, followed by examples of derivation of test specifications for specific equipments and allocation of emission requirements among multiple components of a system. Where specific limits have already been established by regulatory bodies, those specific limits supersede limits herein.

The discussion in this section is restricted to narrow-band emissions and narrow-band immunity. The more complex problems for setting guidelines for broadband emissions will be treated at a later time.

6.1 Protection of Radio Transmissions. Interference with a radio frequency system or other susceptible equipment is a function of the magnitude and character of the radiated signal, the immediate electromagnetic environment, and the characteristics of the susceptible system or equipment. For economic reasons, the energy used in radio transmissions is the minimum required to achieve useful communication. This energy is a direct function of the ambient noise level.

A widely used summary of the anticipated median outdoor values of natural and man-made noise (expressed in terms of noise figure F_a in decibels above kTB, where k is Boltzmans constant, T is 290 Kelvin, and B is receiver bandwidth in Hz) is given in Fig 1 [3].

Although noise is accurately described by the power spectral density as in Fig 1, it is more common to prescribe limits on radiated noise in terms of field strength. In Fig 2 the noise environment of Fig 1 has been translated to field strength as seen by a receiver of 10 kHz bandwidth using an electrically small nondirectional antenna. The 10 kHz bandwidth is taken as typical of communication receivers and of entertainment AM broadcast receivers.

It should be noted that the "quiet rural areas" curves of Figs 1 and 2 represent locations chosen to be as free as possible of manmade noise. The presence of even a small number of automobiles, power lines, or business or residential machines would change the environmental conditions to those of the "rural areas" curve. The ambient noise median is fairly constant in the range of 5–25 dB (μV/m) at higher frequencies as set by manmade noise and increases at frequencies below about 2 MHz as set by atmospheric noise [4], [7], [10], [11], [15], [17], [22], [28], [29].

The choice of the particular numbers to be used for guidelines to meet noninterference objectives is not amenable to exact analysis. Data are not available describing the relation be-

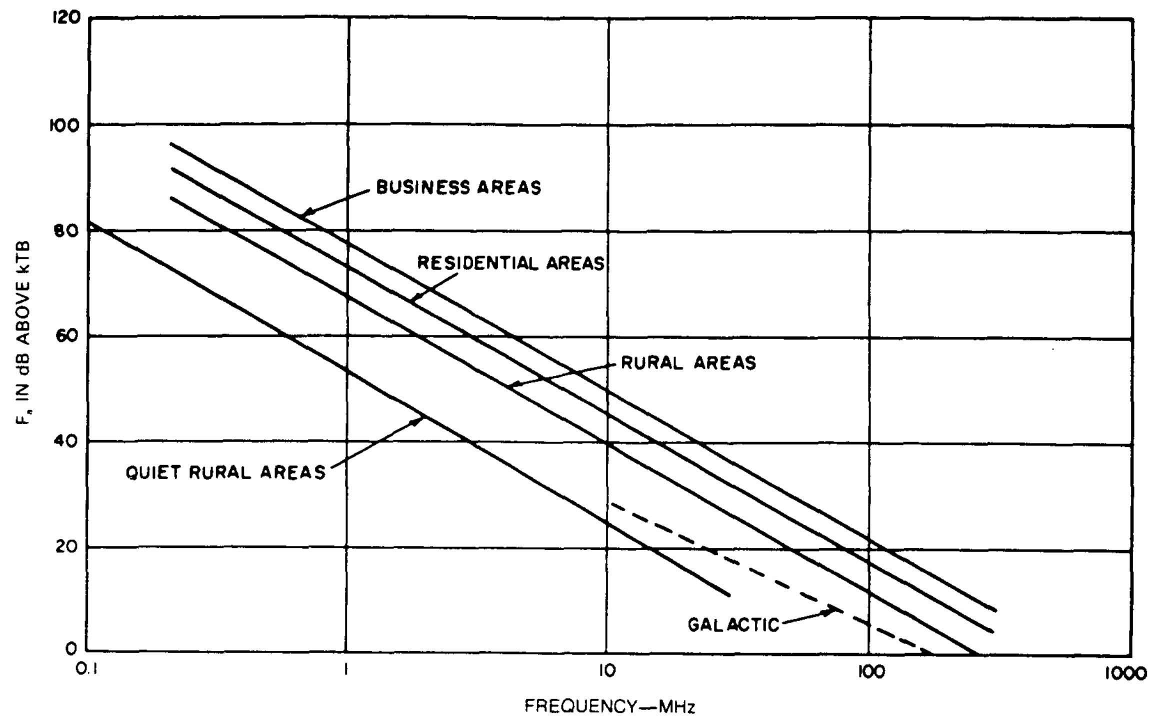


Fig 1
Median Values of Radio Noise Power (Omnidirectional Antenna Near the Surface of the Earth) (From Reference [28])

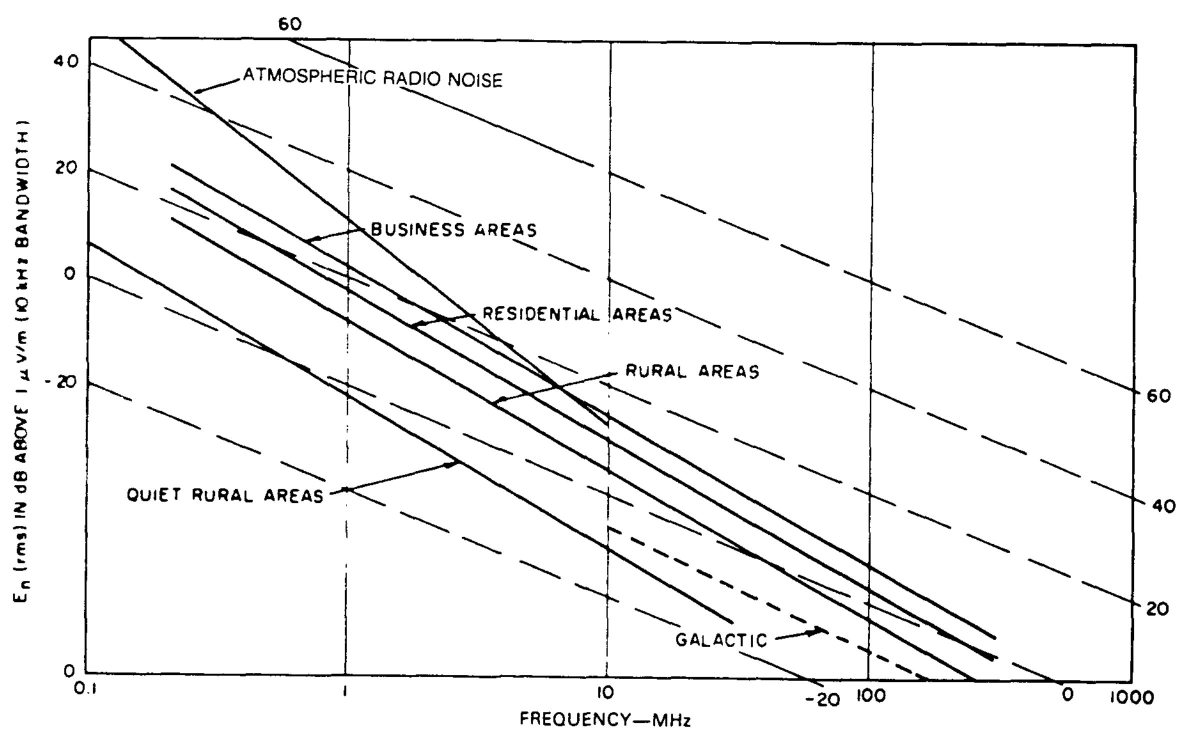


Fig 2
Median Values of Radio Noise (Omnidirectional Antenna Near the Surface of the Earth) (Converted to Field Strength from Fig 1)

tween a given emission limit and the number of interference cases observed or of the impact of various levels of radiation reduction. In general, at lower frequencies, below about 1 MHz, the permitted emission levels should not raise the noise level above the atmospheric noise at a somewhat arbitrary, but specified distance from a given radiating source. This distance is sometimes referred to as the "protection distance." Since the expected level of interference at the protection distance is at or below the ambient level, measurements must either be made at a distance less than the protection distance or in a shielded enclosure of some type.

Two protection levels, based upon two particular classes of environment, residential and commercial, have the potential for reducing costs while still providing adequate protection. With these considerations, a two-tier protection limit plan is chosen. One set of limits applies to equipment used in a commercial / industrial environment where the ambient noise level tends to be high and the likelihood of sensitive receivers is low. A second stricter limit applies to equipment that will be operated in a residential / domestic environment where noise levels tend to be lower and where there are generally larger numbers of sensitive receivers. This concept will usually provide a practical and economic approach to interference control.

The distance at which the protection / radiation limit should be applied could reasonably vary from as little as 1 m (meter) to as much as several hundred m. These distances are primarily limited at the close range by the dimensions of the measuring equipment and the problems of making accurate measurements in the near-field region. At distances much in excess of 30 m, the signal levels of devices that will meet the requirements will in many cases be at the same or lower levels as the ambient noise and may not be capable of resolution. A protection limit specified at a measurement distance of somewhere between 3 and 30 m is preferable when measurement logistics and typical noise source, receiver, and antenna characteristics are considered.

The measuring / protection distance is set at 30 m for the industrial / commercial environment and at 10 m for the residential / domestic environment. Other measuring distances, such as 3 m, may be used if the results are carefully extrapolated to 10 or 30 m. Extrapolation will be considered later in this section. This plan is consistent with practices of various governmental regulatory commissions and international standards bodies [12], [13], [19], [20].

Measurements should be made in accordance with ANSI C63.4-1987 [2]. References [3] and [18] also provide information on measurements. References [2], [3], [12], [13], [18], and [19] give further information on recommended test site characteristics.

Manufacturers and users are advised to refer to any appropriate standards which may apply to their particular types of equipment. Industrial, scientific, and medical radio frequency equipment limits are covered in references [14] and [20]. Proposed ANSI standard PC63.8 (see 7.2, footnote 9) is a compendium of standards in current use. Stricter technical emission limits may be required for special situations such as on-board aircraft or for military applications.

6.1.1 Radio Transmission Protection Guidelines, Normal Conditions. In the absence of any other standards, the following requirements will assure that a reasonable level of protection is given to equipment operating in the vicinity of the equipment to which these standards are applied.

The radiated emission guideline is shown in Fig 3. For frequencies below 800 kHz, the permissible noise level increases inversely with frequency in approximate conformance to the atmospheric noise curve of Fig 2. Above 800 kHz the level is constant to 230 MHz where the permitted level increases slightly. Two measuring distances are used.

For equipment that is to be used in an industrial / commercial application, the radiated emission requirements measured at a distance of 30 m in any direction from the equipment, or, for equipment that is to be used in a residential / domestic application, the radiated emission requirements measured at a distance of 10 m in any direction from the equipment should not exceed the following electric field strength:

Frequency of Radiation	Quasi-Peak Limit: Field Strength (μV / m)	Field Strength [dB (μV / m)]
Below 800 kHz	$24\,000 \div f^*$	$87.6–20 \log f^*$
800 kHz–230 MHz	32	30
230–1000 MHz	70	37
1000–10 000 MHz	70	37

* Where f is frequency in kilohertz.

(The stricter limit shall apply at the transition frequency.)

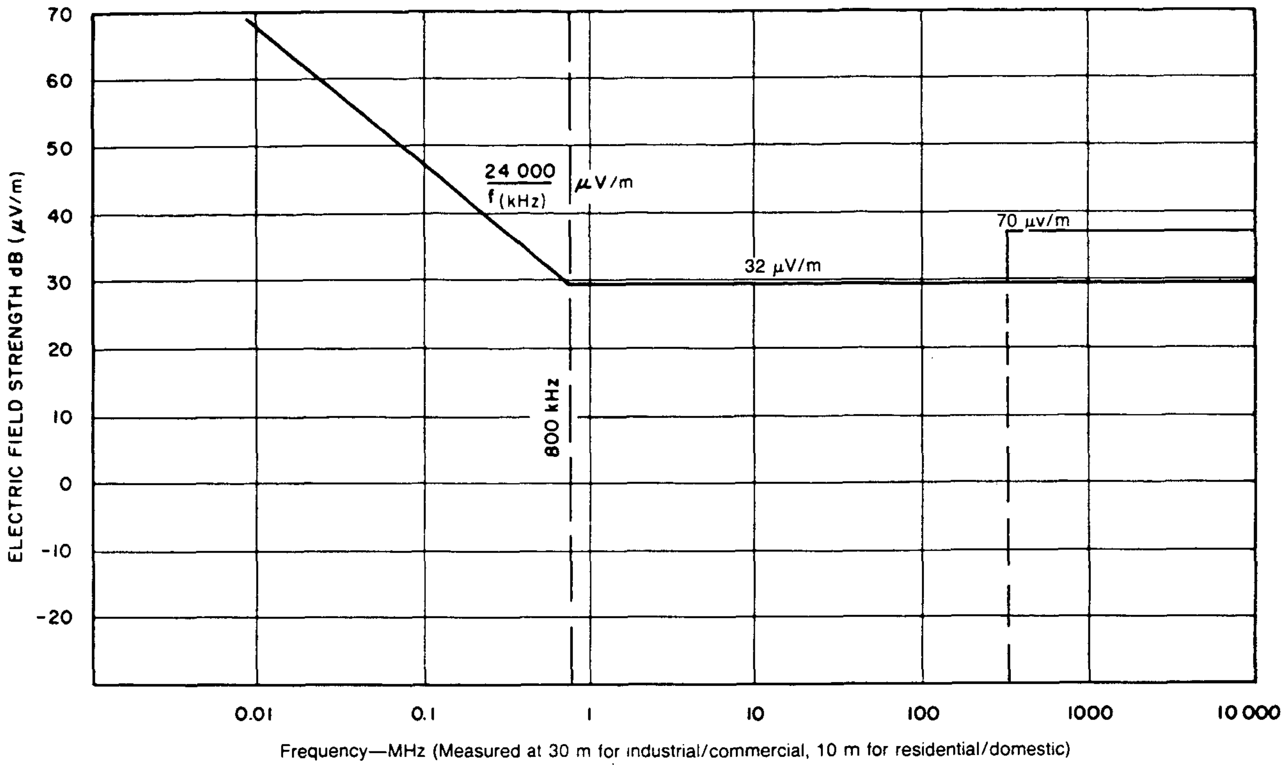


Fig 3
Radiated Emission Guideline

In general the measuring distance should be no less than the largest dimension of the device being measured and no less than the largest dimension of the measuring antenna. Measurements should be made at the specification distance if at all possible.[3]

6.1.2 Radio Transmission Protection Guidelines, Special Conditions. Under certain circumstances, different ambient levels may exist and different protection distances or levels may be appropriate. In such cases, for example, the relaxation of the limits for industrial areas may not be appropriate, and the residential limit might be considered as an alternate. Still other limits might be appropriate for equipment that might be used on aircraft with sensitive navigation equipment which operates in the fuselage in an ambient noise environment well below that shown in Figs 1 and 2.[4] Recommended guidelines in such special situations are under consideration at the present time.

[3] It is understood that a radiation level expressed (as shown in Fig 3) in $\mu V/m$ implies electric and magnetic field levels related by the free space impedance of 377 Ω. It is true that the free space impedance may not hold in the near field, that is, at frequencies where the measuring distance is less than $\lambda/2\pi$ where λ is the wavelength in meters (frequencies below 1600 kHz for a measuring distance of 30 m and frequencies below 4800 kHz for a measuring distance of 10 m). Extrapolation of the electric field limit values at a particular frequency to a different measuring distance requires a knowledge of the source of the emissions. In the simplest case, this would be either a small electric dipole or a small magnetic loop. Extrapolation of the limits at a particular frequency to distances less than $\lambda/2\pi$ requires extrapolation of the level at that frequency back to the $\lambda/2\pi$ distance using a $1/d$ extrapolation and then further extrapolation from the level at the $\lambda/2\pi$ distance to the final distance using a $1/d^3$ or $1/d^2$ relation (depending on an electric or magnetic source, respectively). Extrapolation of the limits at a particular frequency to distances greater than $\lambda/2\pi$ requires that the level at that frequency first be extrapolated to the $\lambda/2\pi$ distance using a $1/d^3$ or $1/d^2$ relation (depending on whether the source is electric or magnetic, respectively) and then further extrapolating the limit from the $\lambda/2\pi$ distance to the final distance using a $1/d$ relationship. It follows that limit extrapolation for distances greater than 10 m above 4800 kHz or 30 m above 1600 kHz requires only a simple $1/d$ extrapolation. Thus, translation of the guidelines requires a knowledge of the type of source causing the emissions.

[4] The Federal Aviation Administration reports that the industrial guideline limits may not be adequate to protect navigation systems used on aircraft from equipment located on legal airport approach air routes or from consumer products carried on board aircraft by passengers.

6.1.3 Conducted Emission Objective. Common-mode emissions occur on one or more conductors and are measured with respect to ground. The recommended common-mode conducted emission objective level is shown in Fig 4. The conducted emission level of Fig 4 is derived from the previously defined radiated emission level of Fig 3. The proposed level is related to the radiated electric field limit in terms of a parallel wire line model in which the parallel line consists of the actual current carrying conductor and an image reflected in the ground plane carrying equivalent current in the opposite direction. Such a line, if terminated in its characteristic impedance, has a ratio of electric to magnetic field equal to that of free space (377 Ω), and for a given conductor height above the ground plane (half of the conductor separation of the equivalent two-conductor line) the current guideline can be chosen to roughly correspond to that producing the radiated electric field level of Fig 3. The guideline of approximately 3 mA or 69.5 dB(μA) shown is chosen to correspond to a field of 32 μV / m at 30 m for a conductor height of about 15 cm above the ground plane. The guideline is cut off at 30 MHz since conducted emission is generally negligible above the 30 MHz owing to line losses.

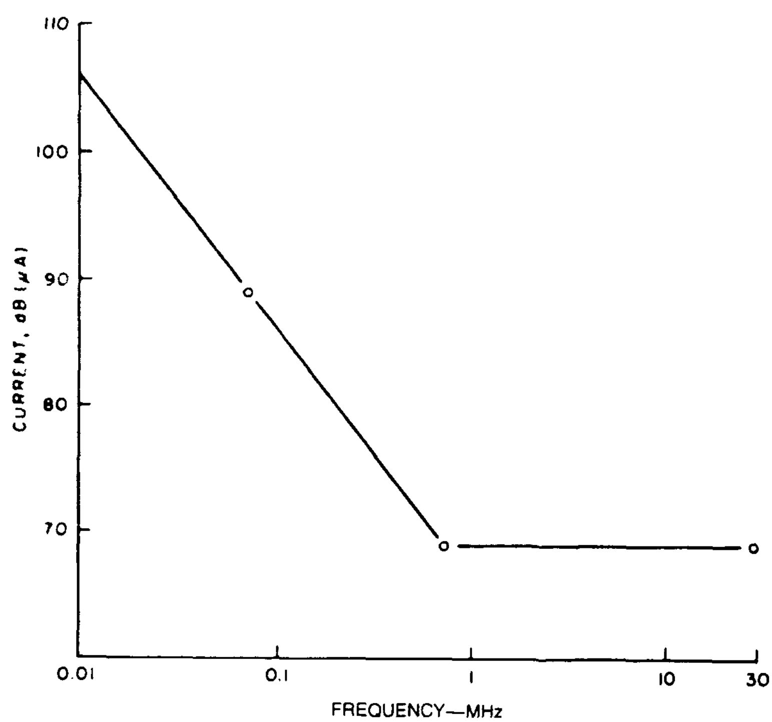
The proposed guideline as shown in Fig 4 then becomes

Frequency of Emission	Common-Mode Current (mA)
Below 800 kHz	$2400/f$ (kHz)
Above 800 kHz	3

One method of making the test for conducted emission is spelled out in [2].

In addition to the above guideline that uses a current probe to measure the common-mode currents in all cables, the use of a line impedance stabilization network (LISN) to measure the noise voltage on ac power leads is recommended [2], [19], [20]. The recommended limits for equipment to be used in an industrial, commercial, or business application are, per [19]

Fig 4
Common-Mode Conducted Emission Guideline



Frequency Range (MHz)	Quasi-peak		Average	
	dB/μV	μV	dB/μV	μV
0.15–0.50	79	9000	66	2000
0.50–30	73	4500	60	1000

NOTE: The stricter limit shall apply at the transition frequencies.

For equipment designed to be operated in a residential environment the limit is, per [19].

Frequency Range (MHz)	Quasi-peak		Average	
	dB/μV	μV	dB/μV	μV
0.15–0.50	66–56	2000–630	56–46	630–200
0.50–5.0	56	630	46	200
5–30	60	1000	50	317

NOTE: The limit decreases linearly with the logarithm of the frequency in the range 0.15 to 0.50 MHz. The stricter limit shall apply at the transition frequencies.

The foregoing discussion and limits apply most appropriately to power line conductors or to emissions from unshielded leads within 30 m of the emitting equipment. Different limits may be more appropriate for other applications. For example, limits for conducted emissions above a frequency of 4 kHz from terminal equipment intended for connection to the public telecommunications network may be found in Paragraph 68.308 (e) of the FCC 47 CFR 68.

6.2 Emission Allocation for Components of a Large System. In acquiring support evidence of system compliance, it may be desirable to test subsystems. In order to ensure that the complete system will be compliant when subsequently tested, the total-system radiated emission limits must be allocated among the subsystems. When the emission source is a system composed of a multiplicity of subsystems, a radiation design objective can be set for each of the subsystems types. This consists of allocating the total-system emission requirement among the subsystems on the basis of the expected number of each type of subsystem in the system and the anticipated additive properties describing the way emissions from the subsystems or equipment units add together. Additive properties depend on the degree of similarity of the various equipment units and on synchronization of the signals from the various emitters. The properties range from peak addition (6 dB increase for doubling the number of equipment units) for identical emissions that are synchronous in both frequency and phase to zero addition for emissions which are constrained to never occur in the same frequency detection band.

Allocation procedures should be engineered on a system basis by the appropriate systems engineering group. Coordination must be maintained across all subsystems so that the occurrence of two or more strong spectral lines within the same 100 kHz bandwidth will be considered and handled appropriately. In the absence of any allocation procedures better suited to a specific system being considered, either of the allocation procedures that follow may be used. The term *synchronously operated subsystems* in these procedures refers to subsystems that are frequency and phase synchronized to a common clock. The term *subsystem margin* refers to the amount in decibels by which the radiated emission limits for the subsystems under test should be below the corresponding limits for the entire system.

6.2.1 Allocation Method 1

Allocation Procedure 1

For synchronously operated subsystems contained within a common building, the margin M required for a subsystem at any given frequency is given by

$$M(\mathrm{dB}) = (10 \log_{10} NS) + E + S + LE + LM \quad \text{(Eq 1)}$$

where

NS = the maximum number of synchronously operated subsystems in one row of equipment (lineup) which contains the subsystem under test

E = 6 dB measurement error allowance

S = 0 to −8 dB building shielding allowance, depending on building characteristics and whether building wall attenuation can be considered as part of the equipment

LE = 0 or −3 dB if, respectively, the subsystem appears or does not appear in an external lineup[5]

[5] Equipment appearing in an internal lineup does not contribute as heavily to external emissions as equipment located on the periphery of the equipment complex. The intervening exterior lineup provides some attenuation of the signals emanating from the interior lineup owing to both the distance and the presence of the intervening equipment.

LM = 0 or 3 dB if, respectively, the subsystem appears or does not appear in more than one lineup[6]

The margin required for a nonsynchronous subsystem is given by

$$M(\text{dB}) = (5 \log_{10} NN) + E + S + LE + LM \quad \text{(Eq 2)}$$

where

NN = the maximum number of nonsynchronous subsystems in one lineup which contains the subsystem under test,

and the other parameters are as previously defined.

6.2.2 Allocation Method 2

Allocation Procedure 2

For synchronously operated subsystems the margin required for a subsystem is obtained from

$$M(\text{db}) = 10 \log_{10} \text{PDR} \quad \text{(Eq 3)}$$

where PDR is the power dissipation ratio, the power dissipated by the subsystem under test divided by the power dissipation of the entire system. For the nonsynchronous case the margin required for a subsystem is obtained from

$$M(\text{db}) = 5 \log_{10} \text{PDR} \quad \text{(Eq 4)}$$

with PDR as defined for the synchronous case.

6.3 Immunity (Susceptibility).[7] Electronic devices must frequently operate in the presence of external radio frequency (rf) fields. These may be due to nearby fixed radio transmitters such as those in the entertainment broadcast service, mobile radio transmitters such as citizens band or mobile radio-telephone units, or noncommunication rf radiators such as industrial heating or medical diathermy machines. When in close proximity to these radiators, the rf fields can be of sufficient magnitude to result in interference into such devices as entertainment and telecommunications electronic equipment or in malfunction of such devices as electronic control circuits. Even nearby sources of relatively low-level emission from incidental radiating devices with microprocessors may cause interference with radio receivers. In this section, only the higher power sources of rf interference and their effects on devices not tuned to the same frequency are addressed. These sources may be modulated and, in fact, may affect the victim equipment as a consequence of the modulation as well as the radio frequency carrier signal strength.

Paralleling the case of rf emission control, setting immunity guidelines strict enough to always avoid interference is not economically practicable, so the chosen set of guidelines must provide protection for most of the units without causing an undue cost penalty to the many units which never encounter high rf fields. As in emission, the immunity coupling mode may occur by direct response to electric or magnetic fields or by conduction of induced or directly coupled signals on connecting leads and power cords.

6.3.1 Radiated Immunity. Definitive studies of the percentage of electronic devices in homes or businesses that encounter high rf fields are limited. It is known that rf fields at some locations can be very high as, for example, 150 dB (μV/m) (32 V/m) 200 ft away from a 50 kW nondirectional AM broadcast transmitter antenna or 20 m directly in front of an 8 dB gain amateur antenna fed with 1200 W peak effective power. Even higher fields may exist in extreme cases. However, these extreme locations constitute a very small portion of total locations where electronic equipment is used. Probably less than 5% of these locations experience fields greater than 1 V/m [15], [17], [22]. Experience has shown that most electronic equipment can be designed to withstand electromagnetic fields in the order of 1 to 5 V/m with very little increase in production design cost, but that design complexity usually goes up sharply as the immunity level is raised beyond that.

On the basis of this background, it is proposed that the minimum immunity guideline for electronic equipment be placed at 1 V/m for the electric field and an equivalent free-space conversion for the magnetic field for the entire frequency range (Fig 5). It is suggested that this limit be applied to as much of the spectrum as possible to account for a continuous mode of immunity response due to the resonance problems caused by variations in lead lengths and cabinet or device dimensions. It is to be under-

[6] Equipment appearing in more than one lineup does not increase emissions in a linear fashion since whichever lineup is closest to the exterior wall will be the dominant source of emissions when measured at a distance from the complex of equipment.

[7] Immunity is the positive view of susceptibility. Both terms are used interchangeably, although immunity is preferred.

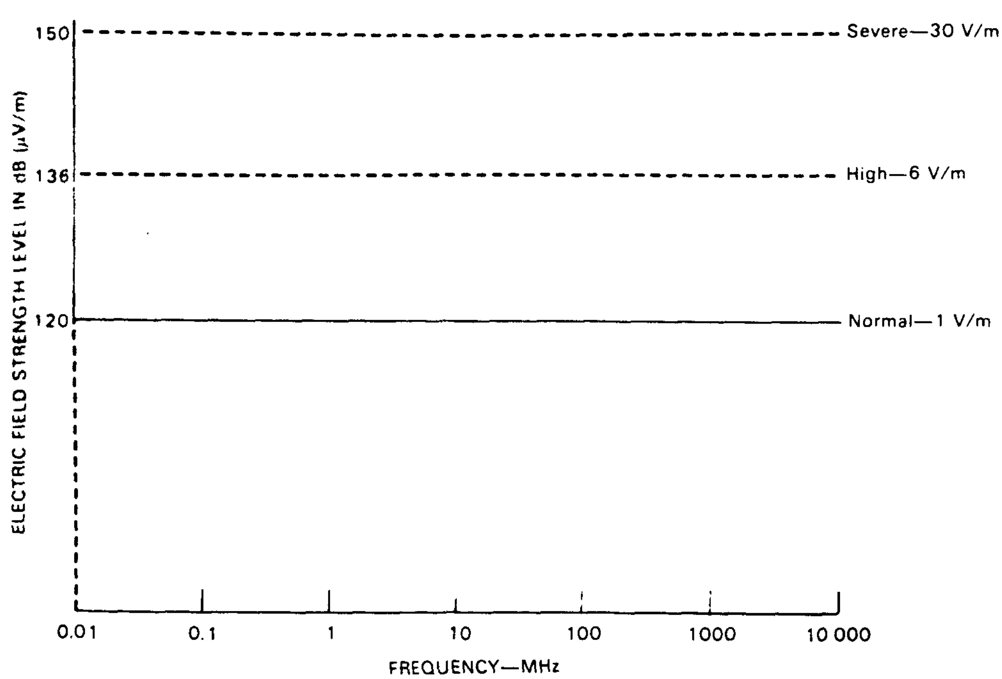
stood that some devices will encounter higher fields and must be specially modified or shielded to attain interference-free operation. Those devices whose reliable operation at all locations is essential for any reason should be designed for higher immunity levels as required for their application. These devices normally represent a very small proportion of the total population, and a decision to meet the higher immunity levels must be decided on an individual basis. Examples are shown as dotted lines on Fig 5.

6.3.2 Conducted Immunity. Fig 6 shows guideline levels of conducted immunity. The top line shows the immunity for power line voltages in the differential mode. This requires a 1 V common mode immunity at frequencies above 10 kHz. Usually equipment can be designed to meet it without too much difficulty, except possibly in the case of some radio receivers operating in the frequency range above 1 MHz.

The common-mode conducted immunity curve as shown in Fig 6 is presented for discussion purposes. It refers primarily to signaling lines and is based upon voltage induced in a typical closed circuit path which would represent, for example, a signal line running between two pieces of equipment and an associated ground plane. At low frequencies, the voltage is induced by the changing magnetic flux, and at the higher frequencies either by the changing flux or the corresponding electric field. However, it should be noted that in circumstances associated with power transmission lines in which a substantial ground potential rise exists, the voltage could appear directly across a signal circuit via transverse to common-mode unbalances. It might be necessary for the common-mode immunity to be of the order of volts or approximately equal to the differential-mode immunity curve shown in Fig 6.

Limited studies of conducted voltage induced on telecommunications conductors indicate the presence of significant unwanted voltages at frequencies above 10 kHz. Although these voltages have not been statistically categorized, some idea of their levels has been indicated by several small surveys. Measurements at telecommunications equipment locations that did not have immunity problems generally had differential mode voltages of less than 5 mV peak and common mode voltages generally less than 12 mV rms. At locations near (less than 3.7 km) AM broadcast antennas that experience immunity problems, long-term differential mode voltages generally were less than 300 mV rms, and common-mode voltages were generally less than

Fig 5
Minimum Radiated Immunity Guidelines



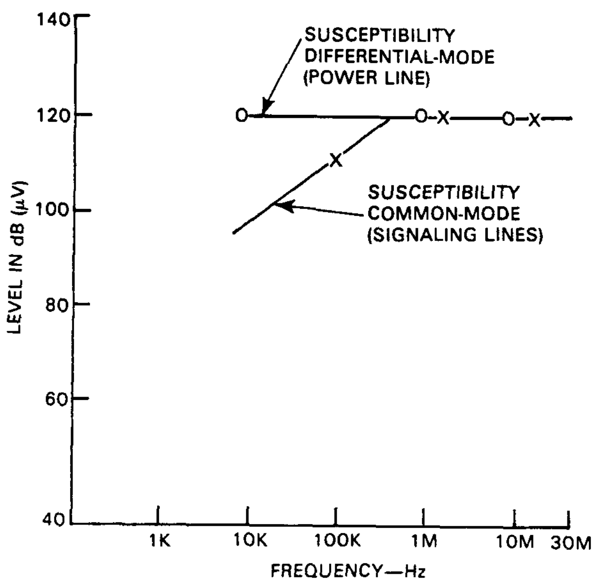


Fig 6
Conducted Immunity Guidelines

11 V rms. Because of the limited extent of the studies, it is probable that long-term voltages higher than these values also occur.

7. References and Documents in Preparation

The following publications shall be used in conjunction with this standard:

7.1 References

[1] ANSI C63.2-1987, American National Standard Specifications for Electromagnetic Noise and Field Strength Instrumentation, 10 kHz to 40 GHz.

[2] ANSI C63.4-1981, American National Standard Methods of Measurement of Radio-Noise Emissions from Low-Voltage-Electrical and Electronic Equipment in the Range of 10 kHz to 1 GHz.

[3] IEEE Std 473-1985, IEEE Recommended Practice for an Electromagnetic Site Survey (10 kHz to 10 GHz).

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7.2 Documents in Preparation[8,9]

[8] When the following ANSI-approved standards are published, they will become a part of the references of this standard: C63.5, Standard Calibrations of Antennas Used for Radiated Emission Measurements in Electromagnetic Interference (EMI) Control; C63.6, Guide for the Computation of Errors in Open Area Test Site Measurement; C63.7, Guide for the Construction of Open Area Test Sites for Performing Radiated Emission Measurements.

[9] When the following draft is approved and published, it will become a part of the references of this standard: PC63.8, Guide to Electromagnetic Compatibility Standards and Procedures.

Appendixes

(These Appendixes are not a part of ANSI C63.12-1987, but are included for information only.)

Appendix A
Measurement of Amplitude Distribution

A1. Noise Amplitude Distribution Requirements

The requirements for an instrument are similar to those described in the basic specifications except as follows.

A1.1 Bandwidth. The intermediate frequency (IF) bandwidth should be as close as possible to the overall bandwidth specified. The IF filter should be designed to have an impulse response giving a minimum[10] number of positive crossings and a rapid decrease in amplitude after its first peak. The impulse response of the IF filter should not prevent accurate measurements at any impulse rate up to $B_i/3$ and for two simultaneous rates of $B_i/10$ and $B_i/5$ which differ in amplitude by at least 40 dB.

The following overall bandwidths are recommended for each indicated frequency range:

Frequency Range (MHz)	B_i
0.15–30	1 and 10 kHz
30.00–400	10 and 100 kHz
400.00–1000	100 and 1000 kHz

NOTE: Suggested limit is ± 10%.

A1.2 Detector and Pulse Counting Circuits. The detector circuit(s) should respond to appropriate levels of spectrum amplitudes using a level-type detector.

A1.2.1 Level Detector. The level detector(s) should include such means as the slideback or threshold method to produce a single pulse for each input impulse exceeding a calibration level. At least eight detectors should be used with each adjustable to respond at a different spectrum amplitude, or a means should be provided to make rapid measurements with a single detector.

[10] A Gaussian response filter has only one positive crossing and a decay slope of 40 dB/Bt.

A1.2.2 Pulse Counting Circuits. Pulse counting circuits should follow each level detector. Counting intervals should be available on a per second basis. It is also desirable to provide total count capability for short time intervals.

A1.2.3 Units of Measurement. The output meter scale or digital display(s) should indicate the impulse rate (per second) exceeding calibrated levels of spectrum amplitudes. At least 8 measurement levels of spectrum amplitude should be provided with an adjustable range greater than 50 dB from the lowest level to the highest. Impulse rate measurements should be provided at each level on a simultaneous or rapid sequential basis. Each pickup device should be supplied with a calibration curve to convert the indicated voltage to the appropriate electromagnetic field, voltage, or current being measured.

The digital output display is recommended; however, a meter-type indicator device can be used if it provides three significant figures.

A1.2.4 Audio Detector. The measuring set should provide an AM audio detector. In addition, an FM audio detector is recommended for frequencies above 30 MHz. The audio amplifier should be provided with a manual gain control. The output should be 10 mW minimum into a 600 Ω load.

A1.3 Measurement Interval. Measurement intervals should be adjustable from 1 ms to 15 s. It is also desirable to provide repeatable periods of measurement that can be initiated by external signals with the data output suitable for automatic analysis.

A1.4 Calibration. The measuring set should be supplied with an impulse-type signal source for substitution-type calibration (see ANSI/IEEE Std 376-1975 [A1]. A variable repetition rate from 1–10 000 Hz is recommended for the impulse generator.

The measuring set should be supplied with a calibration curve that gives the impulse bandwidth for the entire frequency range and for the circuits prior to the detector.

A1.5 Spectrum Amplitude Range. The amplitude range of the measurement should be from 40–120 dB (μV / MHz) in frequency range B, 25–105 dB(μV / MHz) in range C, and 25-85 dB (μV / MHz) in range D. The total amplitude range is a function of the overall noise figure and the impulse bandwidth. The overall amplitude accuracy should be at least ± 1.5 db. Noise generated by the measuring set itself should be measured as described in Appendix B and the results presented as an envelope amplitude distribution of the noise.

A1.6 Impulse Rate Range. The impulse rate range of the measuring set should be from 1 Hz to the highest measurable impulse rate (about ½ the impulse bandwidth).

A1.7 Effects of Additive Random Noise. The effects of added random noise on the NAD measurement are shown in Appendix B.

A1.8 Reference

[A1] ANSI / IEEE Std 376-1975, IEEE Standard for the Measurement of Impulse Strength and Impulse Bandwidth.

Appendix B
Measurement Set Envelope Amplitude Distribution

B1. General

Gaussian noise generated in the front end of the measurement set can cause both unwanted impulse counts in the level detector circuits and amplitude modulation of the impulsive noise being measured, which increases the difficulty of calibrating. To show the degree of limitations of a measuring set, an envelope amplitude distribution (EAD) should be furnished for each IF bandwidth and for each operating frequency range.

B2. Method of Measurement

With an impulse generator connected to the input of the measuring set, adjust its output to minimum.

At each operating frequency and IF bandwidth make the following adjustments and measurements:

(1) Adjust the most sensitive level detector to respond on front-end noise to produce an average count of $B_i / 10$.

(2) Connect an attenuator at a convenient location in the measurement set, between the front-end amplifiers and the level detector, which will reduce the gain of the measurement set by 20 dB.

(3) Increase the output of the impulse generator until the threshold level of the most sensitive level detector is reached. Record the spectrum amplitude adjustment of the impulse generator.

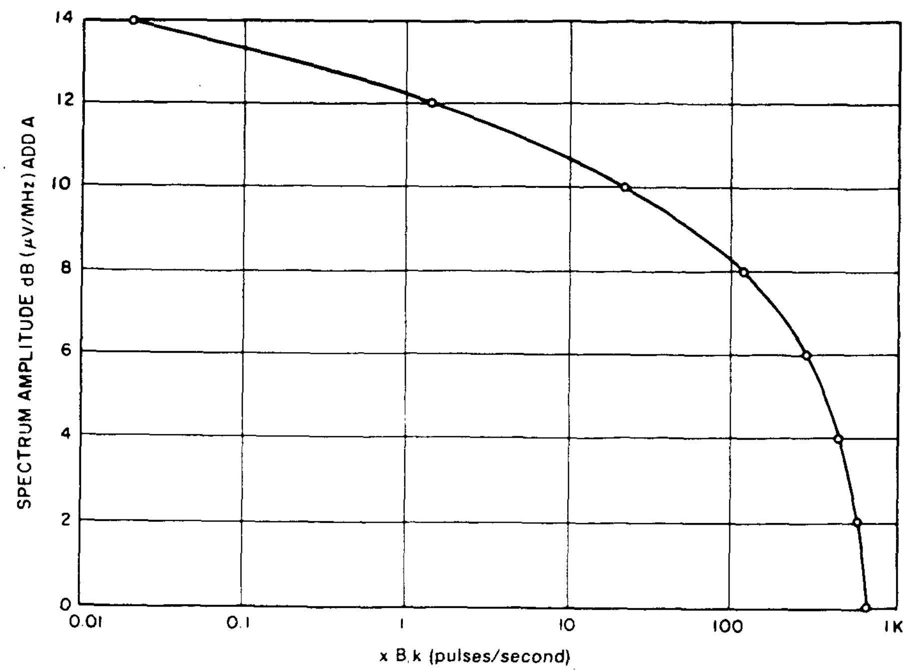
(4) Increase the level of the impulse generator by 2 dB and adjust the next level detector to give a pulse count between 95 and 100% of the generator repetition frequency setting.

(5) Repeat step (4) in sequence for the remaining level detectors. All level detectors should now be calibrated on intervals of 2 dB.

(6) Remove the attenuator connected to the measurement set in step (2). Each level detector should now be calibrated to measure envelope, amplitude at a spectrum amplitude level of 20 dB below that recorded in step (3), and adjusted in steps (4) and (5).

(7) Make several recordings of pulse count for each level detector to obtain an average rate.

(8) Record the results on a graph similar to Fig B1.



The impulse rate f_p is given by the following:
$f_p = 1.084\ B_i E_k^{\ E^2/2}$ (pulses/second)

where
B_i = impulse bandwidth in hertz
E = rms voltage normalized
$A = NF + 47 - 10 \log B_i$ dB (μV/MHz)

where NF is the noise figure of measuring set

Fig B1
Envelope Amplitude Distribution for Gaussian Noise

Appendix C
Amplitude Probability Distribution

Amplitude probability distribution (APD) defines the fraction of total measurement time, T, for which the detected envelope exceeds the various voltage levels. Fig C1 shows a typical APD, with amplitude plotted as the vertical axis against the percentage of time the amplitude is exceeded. APD is a required statistic for predicting the performance of communication systems in the presence of noise. A knowledge of the noise APD is needed to optimize the design of error-correcting coding schemes.

Actual APD measurements require multiple-threshold detectors and numerical analysis of the percentage of time each level is exceeded. However, it has been demonstrated that APD can be plotted quite accurately (±2 dB) from knowledge of only two parameters: (1) the rms voltage level, E_{rms}, and (2) $V_d = E_{rms}/E_{average}$. V_d determines the shape of the curve, whereas the E_{rms} determines its vertical displacement.

Theoretical V_d for Gaussian noise is 1.05 dB; the more impulsive the noise, the higher its V_d ratio. Thus, determining the V_d ratio can supply valuable data relative to the composition of interfering noise.

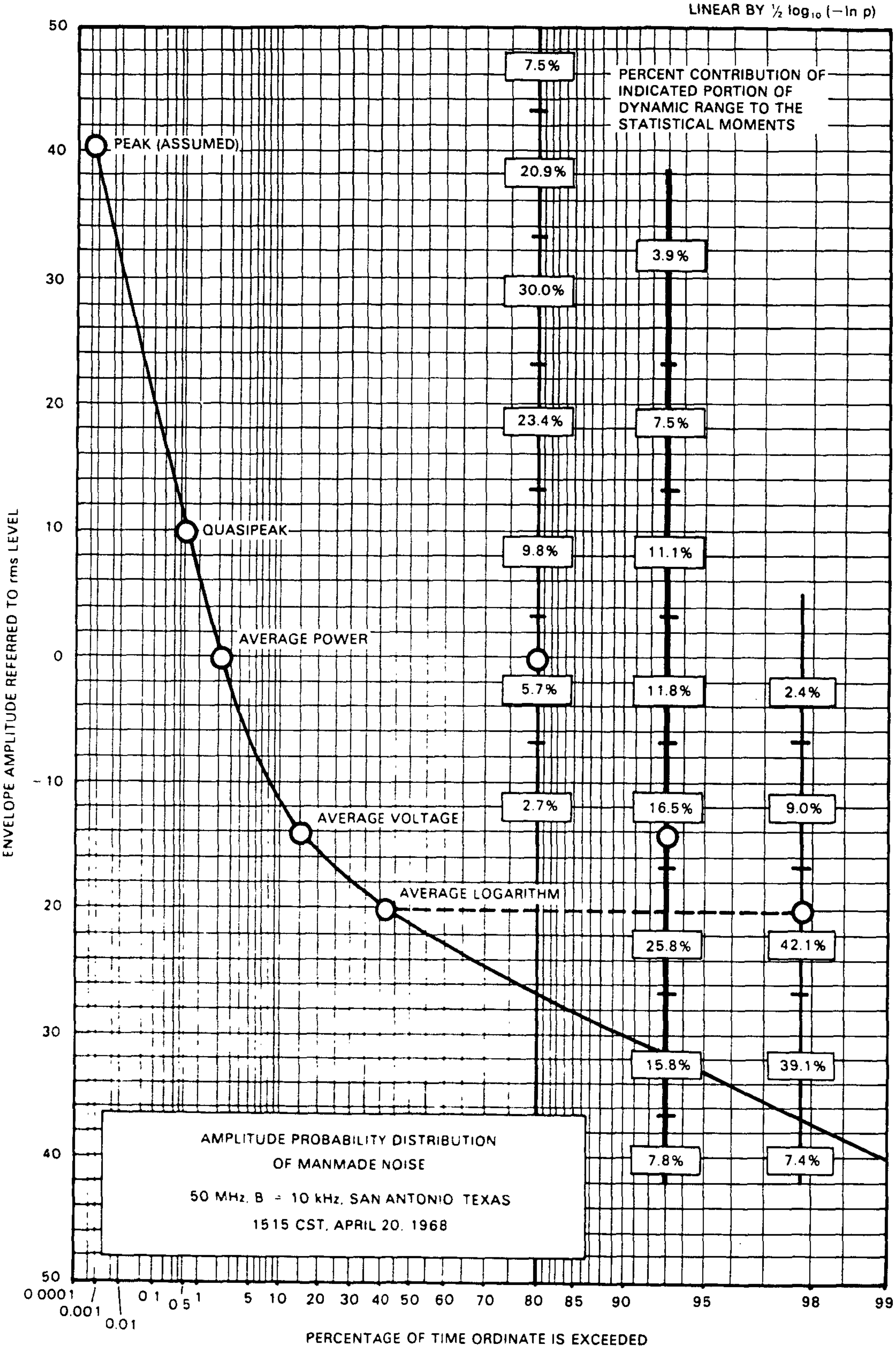


Fig C1
A Typical Man-Made Noise Amplitude Probability Distribution